MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2017/2018

EEL1206 – INTRODUCTION TO MACHINES AND POWER SYSTEMS

(EE, CE, MCE, ME, TE, OPE, NT)

7 MARCH 2018
9.00 a.m - 11.00 a.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of **9** pages including the cover page and Appendix. There are **FOUR** questions in this paper.
2. Attempt **ALL** questions. All questions carry equal marks and the distribution of marks for each question is given.
3. Some useful formulae are given in the Appendix section.
4. Please write all your answers in the Answer Booklet provided.

Question 1

(a) A transformer core with an effective mean path length of 62.5 cm has a 250-turn coil wrapped around one leg. Its cross-sectional area is 16 cm^2, and its magnetization curve is shown in Figure Q1(a). Determine the **total flux in the core** and **the total reluctance of the flux path**, given that current of 0.5 A is flowing in the coil. [6 marks]

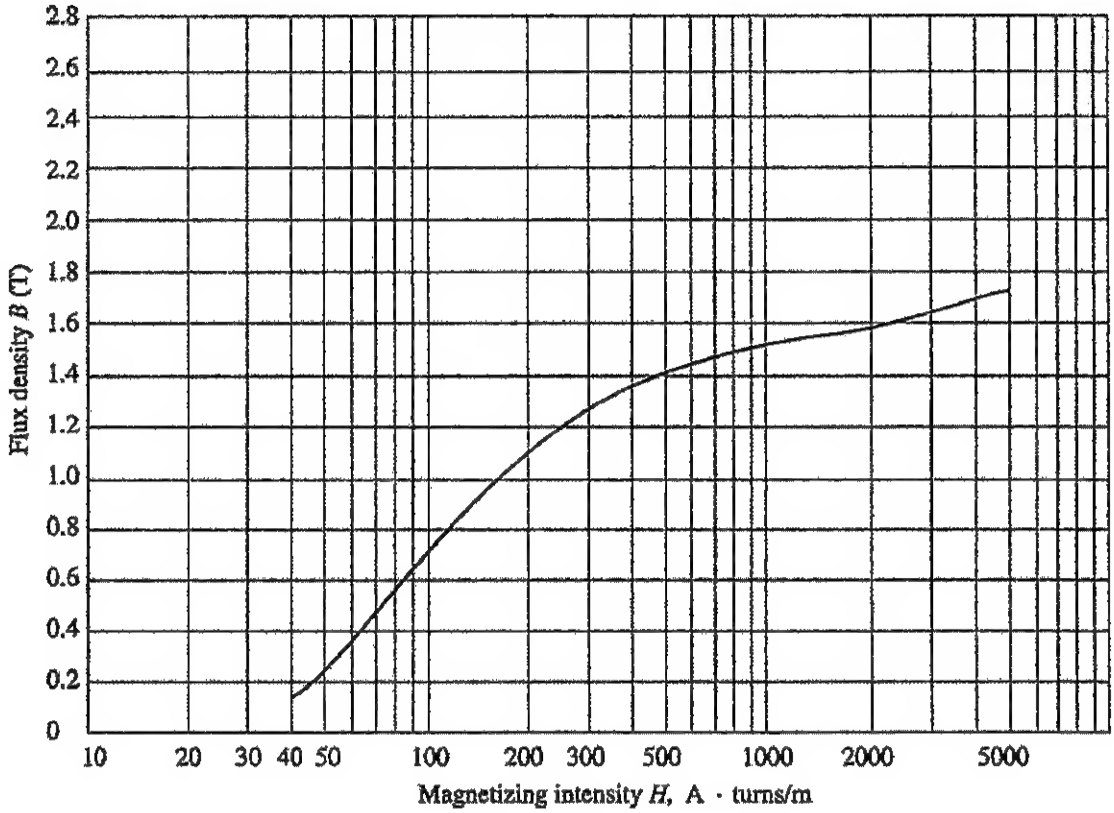

Figure Q1(a)

(b) Figure Q1(b) (on the next page) shows a wire carrying a current of 2.5 A in the presence of a magnetic field. Given that the length of wire, l = 85 cm and the magnetic field density, B = 0.8 T (with direction as indicated in Figure Q1(b)), determine the magnitude and direction of the force induced in the wire.

[4 marks]

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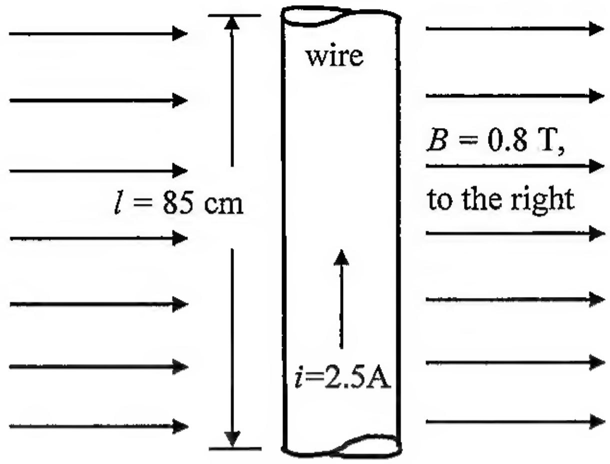

Figure Q1(b)

(c) A balanced delta-connected load having impedance of $51 + j18\ \Omega$ per phase is connected to a three-phase line as shown in Figure Q1(c). The line impedance is $1 + j2\ \Omega$ per phase. The line is supplied from a three-phase source with line-to-line voltage of 415.7 V. Assuming a positive sequence for the source voltages:

(i) Transform the delta-connected load to an equivalent Y-connected load. [2 marks]

(ii) Determine the line currents I_a, I_b, I_c. [6 marks]

(iii) Compute the power factor, the total real and reactive power consumed by the load. [4 marks]

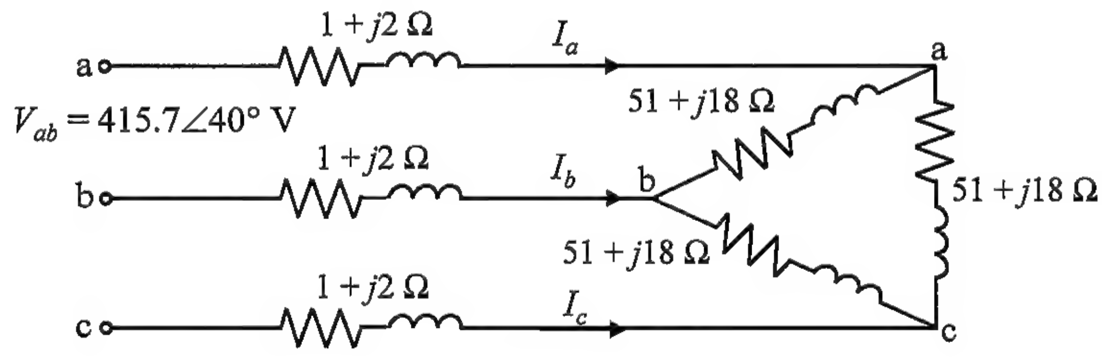

Figure Q1(c)

(d) Draw a diagram showing the power triangle. State the relationship of real, reactive and apparent powers. [3 marks]

Continued...

Question 2

(a) List and explain the **FOUR** main losses that occur in a real transformer.

[6 marks]

(b) A 25-kVA, 4800/240-V, 60-Hz single-phase power transformer is tested with results shown in Table Q2. These test data have been taken from the primary side of the transformer.

Open-circuit (OC) test	Short-circuit (SC) test
$V_{OC} = 4800$ V	$V_{SC} = 48$ V
$I_{OC} = 0.42$ A	$I_{SC} = 6.8$ A
$P_{OC} = 125$ W	$P_{SC} = 264$ W

Table Q2

(i) Determine the values for the parameters in the equivalent circuit of this transformer referred to the secondary side. [7 marks]

(ii) Draw the schematic diagram of the transformer equivalent circuit and label it accordingly. [3 marks]

(iii) Calculate the full-load voltage regulation at 0.8 power factor (PF) lagging.

[5 marks]

(iv) Find the efficiency of the transformer at full load with 0.8 PF lagging.

[4 marks]

Continued...

Question 3

(a) There are **FIVE** major types of DC generators, classified according to the manner in which their field flux is produced. Briefly describe these **FIVE** types of DC generators. [5 marks]

(b) A long-shunt compound DC generator has the following data:

Rated power, $P_o = 6$ kW

Rated terminal voltage, $V_T = 120$ V

Armature resistance, $R_A = 0.15\ \Omega$

Series field resistance, $R_S = 0.06\ \Omega$

Shunt field resistance, $R_F = 30\ \Omega$

(i) Draw the equivalent circuit of the generator. [2 marks]

(ii) Calculate the induced voltage E_A at rated load. Assume there is a brush contact drop of about 3 V. [8 marks]

(c) A 13.8-kV, 60-Hz, Y-connected, six-pole synchronous generator has a per-phase synchronous reactance of 1.2 Ω and negligible armature resistance. The full-load amature current is 1500 A. The field current has been adjusted so that the terminal voltage is 13.8 kV at no load.

(i) Find the speed of rotation of this generator. [2 marks]

(ii) Determine the terminal voltage of the generator if it is loaded with rated current at unity power factor. What is the voltage regulation of the generator ? [4 marks]

(iii) With the aid of a phasor diagram, show how the rated current at lagging and leading power factor affects the terminal voltage. [4 marks]

Continued...

Question 4

(a) Figure Q4(a) depicts the one-line diagram of a power system. The ratings of the different components in the power system are provided below:

Generator, G1:	250 MVA, 48 kV, $R = 10$ %, $X = 90$ %
Generator, G2:	500 MVA, 48 kV, $R = 15$ %, $X = 85$ %
Transformer, T1:	100 MVA, 48/360 kV, $R = 2$ %, $X = 10$ %
Transformer, T2:	80 MVA, 400/24.4 kV, $R = 2$ %, $X = 10$ %
Motor, M:	100 MVA, 20 kV, $R = 20$ %, $X = 80$ %

The transmission line has an impedance of $(25 + j40)$ Ω. A common base of 250 MVA and 48 kV at the generator side is selected for the system.

(i) Determine the base voltages and impedances in Regions 1, 2 and 3. [5 marks]

(ii) Draw the impedance diagram of this power system, and label all the impedances in per-unit. [7 marks]

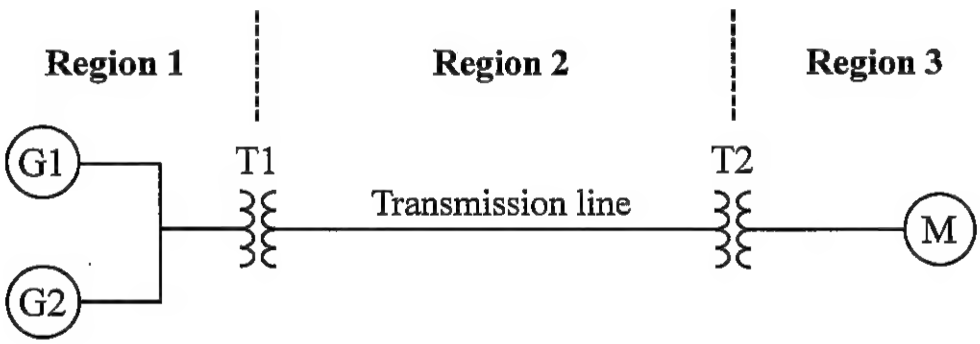

Figure Q4(a)

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(b) An inverse definite minimum time (IDMT) overcurrent relay is used with a 200:5 current transformer to protect a distribution system from overcurrent. The characteristic curves of the relay are shown in Figure Q4(b) on the next page.

(i) Describe **TWO** advantages of using a current transformer in an overcurrent protection system. [4 marks]

(ii) With a suitable example, describe how a 200:5 current transformer works. [2 marks]

(iii) State the main function of an overcurrent relay in an overcurrent protection system. [2 marks]

(iv) Calculate the relay current for a primary fault current of 800 A. [2 marks]

(v) Determine the plug setting multiplier and relay operating time (in seconds) for the relay current in Part 4(b)(iv), if the current tap setting is 2 A and the time dial setting is 11. [3 marks]

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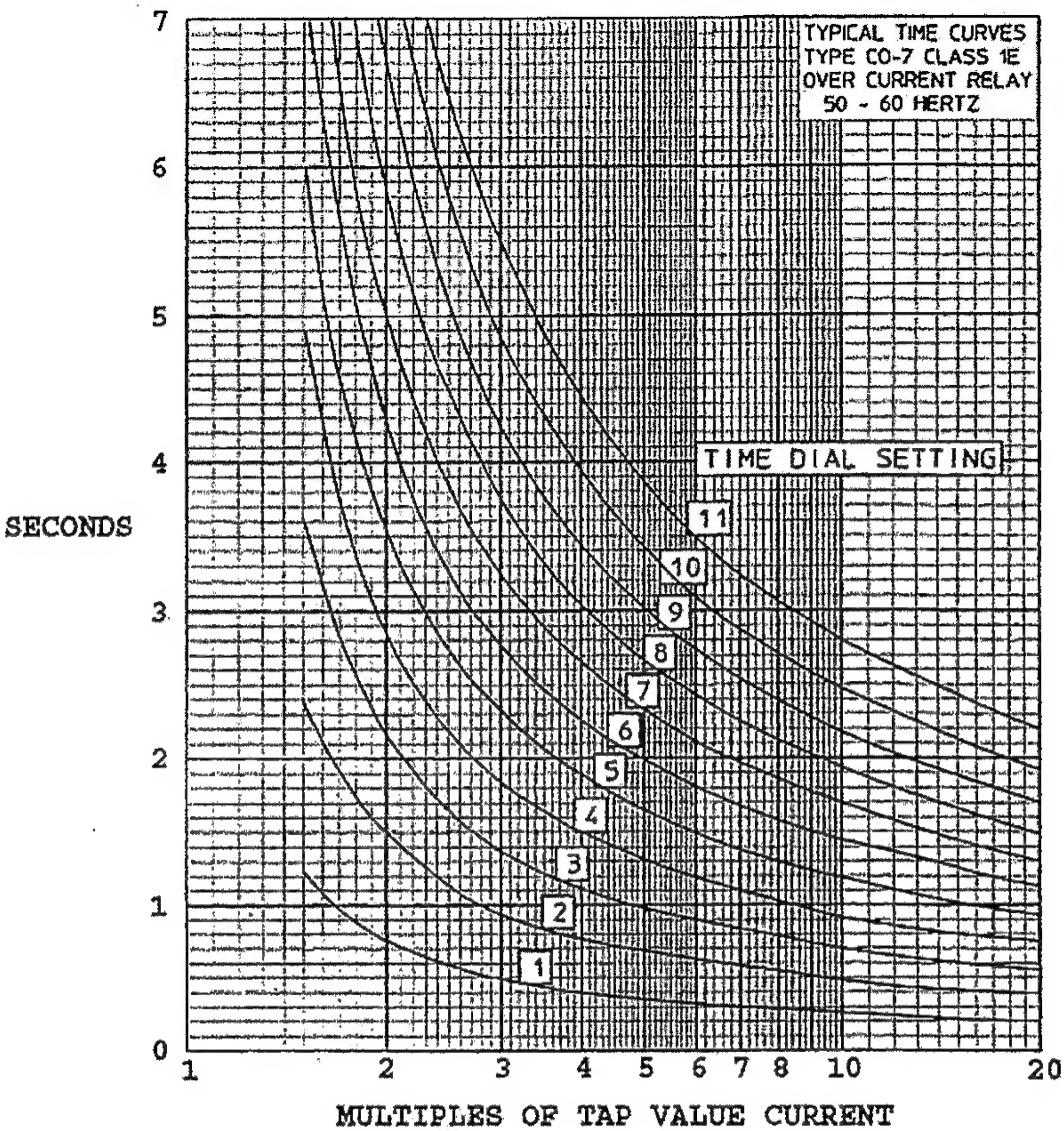

Figure Q4(b)

End of Question

APPENDIX

Magnetic Circuits

$H = \frac{Ni}{l_c}$

$B = \mu H = \mu_0 \mu_r H$

$\phi = BA$

$\Re = \frac{l_c}{\mu A}$

$\mathcal{F} = Ni = \phi \Re = H l_c$

$\mathcal{F} = ilB \sin\theta$

$e_{ind} = vlB \sin\theta_1 \cos\theta_2$

$P = \tau\omega$

Three-Phase Circuits

Y-Connection: $I_L = I_\phi$, $V_L = \sqrt{3} V_\phi \angle 30°$

Δ-Connection: $V_L = V_\phi$, $I_L = \sqrt{3} I_\phi \angle -30°$

Δ-Y Transformations:

$$R_a = \frac{R_{ac} R_{ab}}{R_{ac} + R_{ab} + R_{bc}}$$

$$R_b = \frac{R_{ab} R_{bc}}{R_{ac} + R_{ab} + R_{bc}}$$

$$R_c = \frac{R_{bc} R_{ac}}{R_{ac} + R_{ab} + R_{bc}}$$

Y-Δ Transformations:

$$R_{ac} = \frac{R_a R_b + R_b R_c + R_c R_a}{R_b}$$

$$R_{ab} = \frac{R_a R_b + R_b R_c + R_c R_a}{R_c}$$

$$R_{bc} = \frac{R_a R_b + R_b R_c + R_c R_a}{R_a}$$

$P_T = 3|V_\phi||I_\phi| \cos\theta = \sqrt{3}|V_L||I_L| \cos\theta$

$Q_T = 3|V_\phi||I_\phi| \sin\theta = \sqrt{3}|V_L||I_L| \sin\theta$

$S_T = 3|V_\phi||I_\phi| = \sqrt{3}|V_L||I_L|$

Transformers

Turn ratio: $a = \frac{N_P}{N_S} = \frac{V_P}{V_S} = \frac{I_S}{I_P}$

Equivalent circuit (referred to primary):

$V_S' = aV_S$, $\quad I_S' = \frac{I_S}{a}$

$R_S' = a^2 R_S$, $\quad X_S' = a^2 X_S$, $\quad Z_L' = a^2 Z_L$

$R_{eqP} = R_P + a^2 R_S$, $\quad X_{eqP} = X_P + a^2 X_S$

Equivalent circuit (referred to secondary):

$V_P' = \frac{V_P}{a}$, $\quad I_P' = aI_P$

$R_P' = \frac{R_P}{a^2}$, $\quad X_P' = \frac{X_P}{a^2}$

$R_{eqS} = R_S + \frac{R_P}{a^2}$, $\quad X_{eqS} = X_S + \frac{X_P}{a^2}$

Short-Circuit Test

$Z_{eq} = \frac{V_{SC}}{I_{SC}}$, $\quad R_{eq} = \frac{P_{SC}}{I_{SC}^2}$

$X_{eq} = \sqrt{Z_{eq}^2 - R_{eq}^2}$

Open-Circuit Test

$R_C = \frac{V_{OC}^2}{P_{OC}}$, $\quad S_{OC} = V_{OC} I_{OC}$

$Q_m = \sqrt{S_{OC}^2 - P_{OC}^2}$

$X_m = \frac{V_{OC}^2}{Q_m}$

Voltage Regulation

$$VR = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100\%$$

Efficiency $\eta = \frac{P_{out}}{P_{in}} \times 100\%$

End of Paper